STRIKING PROPERTIES OF JOSEPHSON JUNCTIONS WITH FERROMAGNETIC LINK AND NONUNIFORM INTERFACE

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An interest to Josephson junction devices having ferromagnetic layers in a weal link region is continuously increasing in the last few years. The critical current of a junction with a ferromagnetic (F) spacer exhibits damping oscillations as a function of F-layer thickness and the order parameter phase difference between the superconducting banks could be equal by 0 or π in the ground state. Today the technological achievements open the way for fabrication not only 0 or π-junctions, but also long Josephson contacts having the alternating 0 and π-regions. The difference in the local ground state in these structures is nucleated by introducing some lateral inhomogeneity along their interfaces.

In this work we study theoretically the properties of inhomogeneous tunnel SIFS and SIFNS Josephson junctions, consisted of two superconducting (S) banks separated by a thin dielectric layer (I) and F of FN films, where N stands for a normal metal. We assume that the dirty limit conditions are satisfied in all metals, effective electron - phonon coupling constants are zero in N and F layers and F films have single domain structure with magnetization vector parallel to the film planes. The lateral inhomogeneity of the structure is modeled by a step-like changing of conductivity of S/F or S/N interfaces. To describe the properties of the junction we start with linealized Usadel equations and formulate the two-dimension boundary problem, which have been solved analytically. Based on the developed theory we have found that the boundary inhomogeneity inside SIFS and SIFNS Josephson junctions leads to inhomogeneous distribution of the critical current density $J_C(y)$ along the y- axis, which is perpendicular to the direction of current flow. At the set of the structure parameters under which the junction is closed to 0–π transition in the regions localized far from the inhomogeneity (y=0), in its vicinity (y=0) the $J_C(y)$ exhibits damping oscillation as a function of y and changes its sign under y=0. This, in turn, results in a formation inside the junction of a nonuniform 0-π mini-contact. Characteristic scale of this object is of the order of coherence length ξ_F or ξ_N depending on the type of the structure (SISF or SIFNS) and transport properties of FN interface.

The existence of this mini-contact area inside the structure leads to unusual dependence of maximal Josephson critical current I_c as a function of parallel to interfaces external magnetic field H. If in the regions $|y| \geq \max\{\xi_F, \xi_N\}$, $J_C(y)$ is closed to zero due to 0-π transition, then the shape of $I_c(H)$ is essentially different from the Fraunhofer pattern typically observed in usual Josephson contacts. The maximal full critical current through the junction goes up with increase of the external magnetic field up to a certain value. This value depends on the width of the mini-contact. It may exceed (for SIFS structure) not only the scale typical for Josephson devices, but also even the critical magnetic field of the S-electrodes. This effect could be used for fabrication of sensitive magnetic sensors allow one not only monitoring of the relative changes of external magnetic field (like SQUID), but also to measure of the absolute value of the H.